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(54) Method for manufacturing investment casting cores

(57) A core manufacturing process is disclosed which utilizes a low viscosity distillable binder and firing in a nonreactive refractory sand to provide debindering and sintering of the core in one operation. Cores produced utilizing the disclosed method offer significant savings in processing time while reducing the potential for breakage.

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The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

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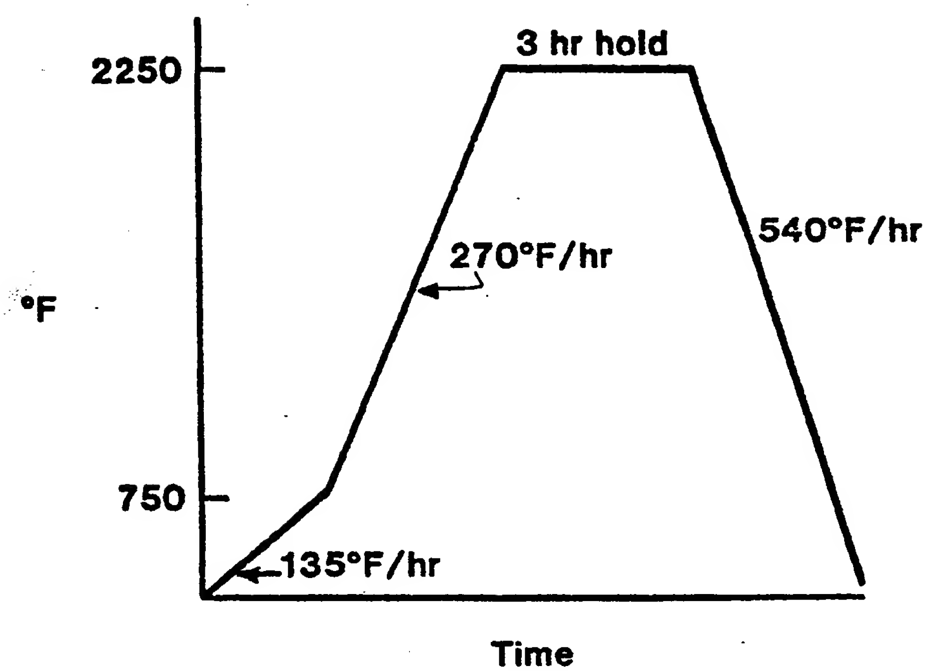

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Method for Manufacturing Investment Casting Cores

Technical Field

This invention relates to ceramic cores utilized in the investment casting process and more particularly to a method for manufacturing ceramic cores utilizing single cycle core firing in refractory sand.

Background Art

Investment casting is extensively used in the production of nickel and cobalt base superalloy blades and vanes for gas turbine engines, particularly those requiring internal cooling passages, providing relatively precise dimensional tolerances and excellent surface finishes. In investment casting, a ceramic mold is formed around a wax pattern with a ceramic core or cores precisely positioned within the wax to simulate the required holes and passages. The wax is removed during a firing operation while the mold and cores remain in place, providing a mold cavity. Molten metal is added and solidified in the cavity and the ceramic cores chemically removed such

as by leaching with a hot alkali solution. Utilizing removable ceramic cores avoids machining or drilling operations which may be difficult to perform on superalloy materials.

Ceramic cores are typically produced by first preparing a core molding composition comprising a ceramic material, such as amorphous silica, and a binder. These materials, as well as any other components added to adjust properties, are blended, fluidized and injected into a mold, forming a core shape which is removed from the mold, placed in a furnace and heated to drive off the binder. In U.S. Patent No. 3,234,308 to Herman, a core is disclosed which incorporates impregnation with a thermosetting resin, such as shellac, prior to debindering, to maintain the core shape after the binder is removed. The core is subsequently fired to sinter the ceramic material, forming a solid core body while simultaneously destroying the resin.

Many core manufacturers use closed ceramic setters which conform to the configuration of the core to accurately support the core and prevent the cores from warping during the firing process, with binder removal and core firing performed in two separate operations. Use of the setter technique with some binder formulations may require up to two weeks between debindering and sintering. Such a long period presents numerous opportunities for breaking or cracking the fragile core, while substantially increasing processing time. Consequently, what is needed in the art is a method of producing ceramic

cores which reduces cracking and minimizes processing time.

Disclosure of Invention

It is an object of the present invention to provide a method for manufacturing investment casting cores which utilizes a single firing cycle for debindering and sintering.

It is a further object of the present invention to provide a single cycle core production process which significantly reduces the time required to produce a core.

These and other objects of the present invention are achieved by utilizing a core production process which includes the steps of preparing a core molding composition, blending with a low viscosity, distillable binder, molding the mixture to a desired shape, embedding the molded shape in a nonreactive refractory sand, and firing the sand and molded core disposed therein at controlled temperatures wherein the binder is drawn by capillary action into the sand where it is evaporated or decomposed. The debindered core, fully supported in the sand, is then subjected to a higher temperature at which sintering occurs.

Brief Description of Drawings

The sole Figure is a graph illustrating a typical core firing program.

Best Mode for Carrying Out the Invention

A ceramic core production process comprises molding compound preparation, core molding, debindering and sintering. Other processing steps may be included such as powder mixing, surface treatment of the ceramic powders, binder preparation, mixing of the treated powder mixture with the binder, forming the molding compound, and, pelletization of the molding compound for uniform feeding in an injection molding machine.

For exemplary purposes, a core molding compound may comprise up to 35 percent by weight zircon, up to 5 percent fumed silica, up to 6.5 percent alumina fiber, balance amorphous silica, with a binder added in an amount sufficient to maintain a molded shape before firing, and a silane coupling agent added in an amount sufficient to produce optimal surface wetting of the powder by the binder. Such ingredients are discussed in the applicants copending application titled "Core Molding Composition", Attorney Docket No. R-2683, filed on even date herewith and hereby incorporated by reference. While an exemplary composition, it will be understood by those skilled in the art that the ingredients and proportions of the composition can be varied to produce cores with different strength and shrinkage properties. For example, silica, alumina and zircon core compositions, and mixtures thereof, may successfully utilize the method of the present invention.

The choice of binder formulation is usually dependent on the particular application and may comprise a mixture of paraffin waxes, lubricants and mold release agents. However, a low viscosity, distillable binder is required to practice the present inventive method. For the purposes of this application, low viscosity refers to the flowability of the binder at debindering temperatures and distillable refers to the ability of the binder to essentially vaporize or decompose at the debindering temperature. It should be noted that small quantities of the binder composition may be non-distillable without deviating from this definition. For example, up to 20% of the binder mixture may remain in the core without sacrificing the benefits of the present invention. In addition, the binder chosen should exhibit a low viscosity at injection conditions to increase moldability; about 10,000 centipoise is exemplary. One such low viscosity, distillable binder comprises 33.3% paraffin wax having a melting point of 131-136°C, 33.3% paraffin wax having a melting point of 144-149°C and 33.3% mineral wax having a melting point of 163-172°C, with an admixture including aluminum stearate, oleic acid and beeswax added as internal lubricants, mold release agents and deflocculants.

After incorporating a low viscosity, distillable binder in the core molding composition, the bindered core composition is molded into a desired shape using either a plunger or screw-type molding machine and conventional molds. While either machine may be used,

best results are generally obtained using one with electronic feedback process control of the injection temperature, injection rate and injection pressure. It will be understood by those skilled in the art that universal molding conditions are not obtainable and that the optimal molding conditions must be determned by trial, however, molding temperatures between 180° and 230°F and pressures of about 4,000 to 10,000 psi are common.

The molded core is removed from the mold and placed in a firing sagger or box containing refractory sand. It is essential that the core be completely embedded in the sand for support and to assure maximum heat transfer. For exemplary purposes, alumina sand having a particle size of about 0.0017 inches is used. However, those skilled in the art will recognize that any nonreactive refractory sand, capable of withstanding the firing temperature, may be used.

The firing sagger is placed in a furnace and a firing cycle initiated. The firing sagger is heated externally with heat transferred through the refractory sand into the core, with temperature gradients possibly forming therebetween. As the molded core is heated, the low viscosity distillable binder is drawn out of the molded core by capillary action into the adjacent sand. The binder then distills off or is decomposed, completing the debindering operation. At this point, the core is very fragile. However, since the sand is essentially fluid, it shifts as the core shrinks and maintains full surface support during the entire core firing

cycle. The temperature is then increased until the sintering temperature is reached, at which point the temperature is held until the ceramic particles sinter, thereby producing a core.

Example

A six pound batch of core molding compound is prepared for the injection molding of a core. The proportions of each ingredient are disclosed in Table I.

Table I

Ingredient	Concentration Weight Percent
amorphous silica	62.64
zircon	27.84
fumed silica	4.12
alumina fiber (5 micron dia x 0.125 inches long)	4.16
silane coupling agent	1.24

The silane coupling agent converts the essentially polar ceramic surface of the compound to a surface of nonpolar nature which is easily wetted by the binder. For illustrative purposes, the silane coupling agent is Union Carbide A1108. After blending, the moist powder mixture is dried for three hours at about 220°F.

The ceramic powder is then mixed with a low viscosity distillable binder in a vacuum blender. The wax binder mixture comprises 33.3% paraffin wax having a melting point of 131-136°C, 33.3% paraffin wax having a melting point of 144-149°C and 33.3% mineral wax, such as ceresin, having a melting point of

163-172°C. In addition, an admixture of beeswax (4 parts), aluminum stearate (12 parts) and oleic acid (8 parts) is added to optimize binder properties. About 13.5% by weight binder is added to the core composition. Mixing time is batch dependent and, for this example, is about three hours at a temperature of 220°F. The molding compound is then extruded and pelletized, preferably using a die face pelletizing technique, for optimum flowability during the subsequent molding process. The pelletized molding compound is stored in a low humidity chamber until required for use.

Ceramic cores are then molded using a conventional plunger-type injection molding machine and conventional molds. The cores are then removed from the molds and packed into alumina sand having a particle size of about 0.0017 inches which is contained in a firing sagger. The sagger is placed in a programmed electronically controlled furnace and subjected to a firing cycle during which the binder is first removed from the core at low temperature without disturbing the core shape, followed by sintering of the ceramic particles at higher temperatures.

Referring to the Figure, an exemplary debindering and sintering firing program is illustrated, for use with the above described core composition. The sand and cores are first subjected to a 135°F per hour temperature ramp, from ambient to 750°F. During the ramp, the binder is removed from the core by capillary action. As the binder is drawn out into the sand, it is evaporated and/or decomposed, thereby

providing debindered cores supp rted in the alumina sand. Any remaining traces of the binder are burned out during the next ramp to the sintering temperature of about 2250°F, which proceeds at 270°F per hour. The cores are held at the sintering temperature for approximately 3 hours, during which time complete sintering occurs between the ceramic particles and solid core bodies are formed. The cores are then furnace cooled, for example, using a 540°F per hour ramp, and the cooled cores removed from the firing sagger and prepared for core finishing and wax pattern molding.

While the preferred embodiment of the present invention is described in relation to a core composition having particular quantities of ingredients, it will be understood by those skilled in the art that various changes in composition may be made to provide additional desirable properties without varying from the scope of the present invention. It will also be understood by those skilled in the art that while a particular debindering/sintering program is illustrated, other variations in times and temperatures may be used without varying from the scope of the present invention.

Having thus described the invention, what is claimed is:

Claims

1. A ceramic core production process which includes the steps of preparing a core molding composition; mixing with a binder; molding said mixture at controlled temperatures and pressures, to form a molded core; and, firing the molded core to effect binder removal and sintering; the improvements which comprise:

mixing said composition with a low viscosity, distillable binder;

embedding the molded core prior to firing in a nonreactive refractory sand; and,

firing the refractory sand and the molded core contained therein at controlled temperatures such that the binder is drawn out of the core into said sand, said core being fully supportable by said sand, said sand and core being subsequently subjected to a sintering temperature, whereby a solid core body is formed.

2. The process of claim 1 wherein said binder comprises 33.3% by weight paraffin wax having a melting point of 131-136°C, 33.3% paraffin wax having a melting point of 144-149°C. 33.3% mineral wax having a melting point of 163-172°C with an admixture of beeswax, aluminum stearate and oleic acid added in an amount sufficient to adjust the binder properties in the core.

3. The process of claim 2 wherein said admixture comprises about 4 parts beeswax, about 12 parts aluminum stearate and about 8 parts oleic acid.

4. The process of claim 1 wherein the firing of said molded core proceeds at a first increasing temperature ramp from ambient to about 750°F, at about 135°F per hour, followed by a second increasing temperature ramp of about 270°F per hour, up to the sintering temperature of about 2250°F, holding for about 3 hours at about 2250°F and cooling said core at a first decreasing temperature ramp of about 540°F per hour.

5. The process of claim 1 wherein said molded core is embedded in alumina sand.

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